Are All Bifacial High-Efficiency c-Si Technologies Equally Sensitive to Potential-Induced Degradation?

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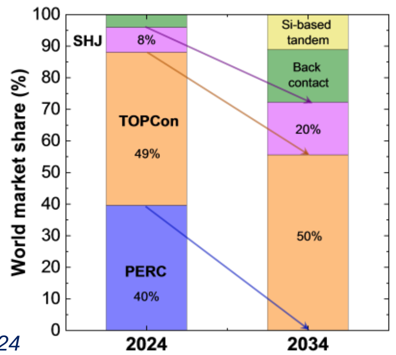
Introduction

- **System voltages are increasing** as means of cost-effectiveness, potentially exacerbating PID phenomena in large-scale installations.
- Novel high-efficiency c-Si technologies (i.e. **SHJ, PERC and TOPCon**), with no significant field track record, have taken over the PV market.
- These technologies, which rely heavily on surface passivation, can be more prone to PID effects.
- **Bifaciality** can also increase the potential for PID.



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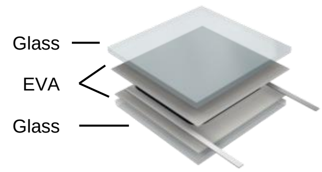
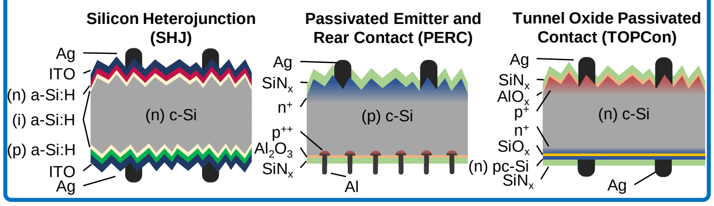
PID Testing

PID testing conditions		
Temperature / RH	Voltage	Duration
85ºC / 85%	-1 kV	96 h → 500 h

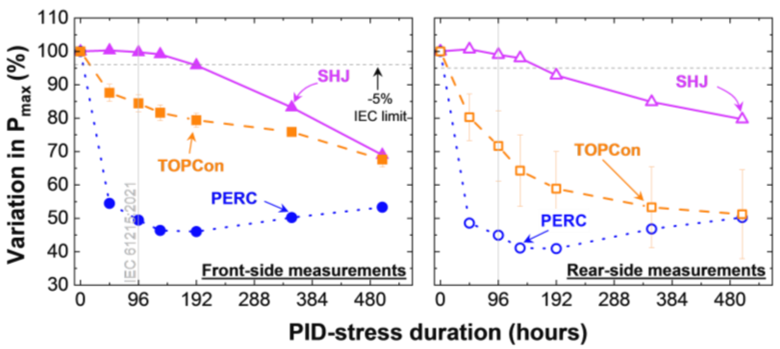


- **Conductive Al tape** is placed at the edges of the module to simulate **metallic frame**.
- Frame is grounded and solar cells are short-circuited.

Bifacial high-efficiency c-Si solar cells

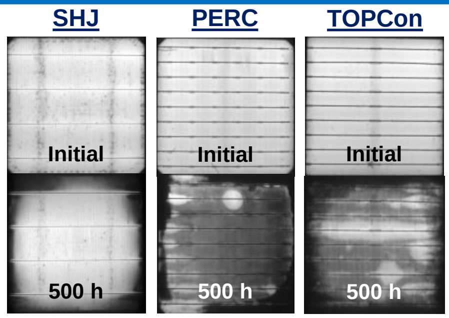


Sensitivity to PID



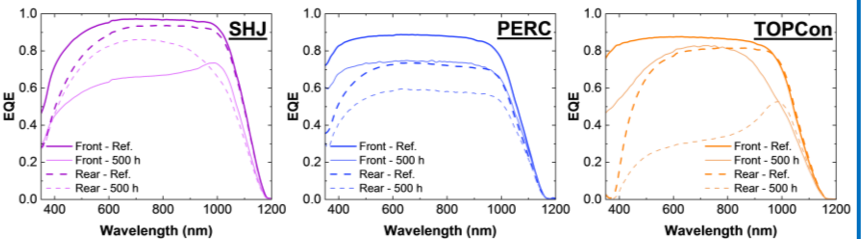
- Different degradation rates and mechanisms.
- Only **SHJ mini-modules pass the standard PID test**.
- Significant difference in degradation between two sides of **PERC** and **TOPCon** cells → **higher degradation at rear sides**, especially for TOPCon cells (~20%).
- **Degradation kinetics:**
  - **SHJ** → linear degradation.
  - **PERC** → saturation after 2x IEC, then recovery.
  - **TOPCon** → linear degradation from front-side measurements, while rear-side measurements reach a plateau.

PID - Degradation mechanisms



- **SHJ degrades at edges**, linearly with increasing moisture within the mini-module[1].
- **PERC and TOPCon** degrade randomly **all over**, with an increased degradation at edges after 500 h → **corrosion**.

- **SHJ** → degradation driven by **front-surface recombination**[2].
- **PERC** → general **material degradation on front and rear sides,** losses in EQE over all wavelengths.
- **TOPCon** → degradation of **boron-emitter** combined with an increased **rear-surface recombination** (tunnel-oxide side) effect.



Conclusions & Perspectives

- Bifacial high-efficiency technologies can be **very sensitive to PID** when encapsulated in G/G module configurations.
- **PERC technology shows highest degradation** under negative PID, while **SHJ the lowest**.
- Degradation mechanisms and kinetics vary from cell to cell.
- Solutions to **mitigate PID** should be studied on a **case-to-case basis** and **tailored to every technology**.

References & Acknowledgements

[1] Gnocchi et al., *Cell Rep.*, 2024

[2] Arriaga Arruti et al., *Prog. Photovolt.: Res. Appl.*, 2024

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